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Aerodynamics Technical Memorandum 406

A USER'S MANUAL FOR THE ARL MATHEMATICAL MODEL OF THE SEA KING MK 50 HELICOPTER: PART I - BASIC USE (U)

by

A.M. Arney and N.E. Gilbert

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A USER'S MANUAL FOR THE ARL MATHEMATICAL MODEL OF THE SEA KING MK 50 HELICOPTER: PART I - BASIC USE

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A. M. ARNEY and N. E. GILBERT

SUMMARY

A mathematical model of the Sea King Mk 50 helicopter, as used in the Anti-Submarine Warfare (ASW) role, has been developed at ARL. This document describes the basic use of the computer program representing this model on the Elxsi 6400. Details are given on setting up the model and running it, first in ASW mode as a means of trimming the aircraft, and then in either ASW, ASE (Auto Stabilizing Equipment), or pilot modes to simulate a desired manoeuvre.

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CONTENTS

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1. INTRODUCTION

A mathematical model of the Sea King Mk 50 helicopter, as used in the ASW (Anti-Submarine Warfare) role, has been developed by ARL to a Royal Australian Navy (RAN) task requirement. This model, which was developed originally on a DEC System 10 computer using the simulation language "CSMP-10(ARL)" (Refs 1-3), has been described in general terms in Refs 4 and 5. Full descriptions of the main components, namely the Aerodynamics/ Kinematics, Control Systems, and Cable/Sonar may be found in Refs 6-11.

Assuming a basic knowledge in using the Elxsi 6400 computer, the use of the computer programs associated with the Sea King model is described in three user manuals. Part I (this one) shows how to set up the model and run it in its basic modes without dunking sonar. The model is first run in ASW mode as a means of trimming the aircraft, i.e. 'flying to trim', and then in either ASW, ASE (Auto Stabilizing Equipment), or pilot modes to simulate a desired manoeuvre. Part II (Ref. 12) provides a catalogue of the many flight trials data files, shows how to access and process the flight data, and then how to run the mathematical model with inputs obtained from the flight data. Part III (Ref. 13) shows how to use the dunking sonar model and demonstrates the use of a cable graphics program.

Transfer of the Sea King model to the Elxsi 6400 computer in 1985 also necessitated transfer of the simulation language. Details on retrieving the files necessary for the modelling component of the language are therefore given here, as well as a brief outline description of the basic structure of the language.

2. BASIC STRUCTURE OF SIMULATION LANGUAGE

CSMP-10 (ARL) is a block oriented simulation language consisting of two parts, the modelling program BOMMP (Block Oriented Mathematical Modelling Program) and output program TRANS (Translation). The model is expressed in coded form with the aid of block diagrams comprising a number of linked modules, called blocks, each one representing a particular function or operation. The language incorporates 'user-defined' blocks written as Fortran subroutines, which enables complex mathematical processes to be handled more conveniently. Each user-defined subroutine may reference any number of 'called' subroutines at a lower level. The Sea King model takes particular advantage of this feature, with complete component models represented in this way.

In the coding, the model is represented by three types of statements - configuration, parameter, and function. The configuration statements describe the blocks used and specify the way in which they are linked together. The parameter statements specify numerical values of parameters associated with the configuration statements, such as integrator initial conditions, while the function statements specify the coordinate pairs used to generate a function. The output program part of the language is capable of producing graphical and tabular results in a variety of formats.

3. FILE RETRIEVAL FROM MAGNETIC TAPE

All the files required for compiling, binding, and running the Sea King mathematical model, together with related programs, may be found on ARL magnetic tape M228, and are listed in Appendix A.

To retrieve these files, a request is made to the operator for tape M228 to be mounted:[1]

```
:MOUNTTAPE M228 -W
:
***From operator at 09:57: Mag tape mounted on tape2
:TAPES
Device Status
```

device	user	volume	type	density	ring
tape1					
tape2		M228	ANSI	6250bpi	No
tape3					

```
No outstanding mount requests for user ae.arney
:
```

Once the tape is mounted, one file may be obtained:

```
:RESTORE SEAKINGMASTERFILES/filename vol=M228 merge=flat seq=1
 -unload +creator
```

If all the files in Sequence 1 are required, add the +subtrees switch:

```
:RESTORE SEAKINGMASTERFILES vol=M228 merge=flat seq=1 -unload
 +creator +subtrees
```

If a list of files is required, the shellfile 'READTAPE' should be restored first. This shellfile, listed below, allows a number of files to be restored without having to repeat the long pathname contained on the command line.

```
:LIST READTAPE
- - SHELLFILE TO RESTORE LIST OF FILES FROM MTAPE
parm file +list +req
- - Init shellvariables,'files'=pathname,'count' is a counter
set filelist '' +declare
set count 1 +declare
set filelist  [cat SEAKINGMASTERFILES/  &
              [file [count]]] +append
- - Start of loop to add list of files to pathname
 label loop
set count [eval count+1]
- - If another file is there add to pathname otherwise restore files
 if [file [count]] then
   set filelist  [cat ",SEAKINGMASTERFILES/"  &
                         [file [count]]] +append
   goto loop
 else
```

[1] For computer terminal input included in this document, messages typed by the user are shown in bold type.

```
   goto restore
 end if
- - Restore files
 label restore
 restore [filelist;noquote] vol=M228 merge=flat SEQ=1 -unl +cre
 :
```

Below is an example showing how READTAPE is used to retrieve all the files necessary for the simulation language modelling program BOMMP.

```
:READTAPE BINDBOMMP,BOMMPLIB,CHKUPR.F,CSMPA.F,CSMPB.F,CSMPC.F,
DUSER.F,FCHECK.F,INTEG.F,MAIN2.F,PTIME.F
BINDBOMMP
BOMMPLIB
chkupr.f
csmpa.f
csmpb.f
CSMPC.F
duser.f
fcheck.f
integ.f
main2.f
ptime.f
**********  RESTORE SUMMARY  **********
11 files restored.
0 files not restored.
0 directories restored.
0 directories not restored.
All requests were found on tape.
:
```

4. DERIVING THE SEA KING MODEL

The Sea King mathematical model SEAKING86 is obtained by combining the modelling program BOMMP with the Sea King component modules. The Fortran source files for each are:

a) Modelling Program BOMMP

CHKUPR.F	-	Checks for upper case letters
CSMPA.F	}	BOMMP routines
CSMPB.F		
CSMPC.F		
DUSER.F	-	Dummy user subroutines
FCHECK.F	-	Checks if file exists
INTEG.F	-	Integration methods
MAIN2.F	-	BOMMP executive routine

b) Sea King Component Modules

BLADIN.F	-	Inputs control movements from flight data
CABGEN.F	-	General functions required by cable model
CABLE.F	-	Generalized cable model
MJW6.F	-	Outputs specific data relating to aerodynamics module
PILOT.F[1]	-	Interactively accepts control movements
SKA86.F	-	Aerodynamics model - including interface with configuration statements
SKC83.F	-	Cable model - including interface with configuration statements
SKS86.F	-	Systems model - including interface with configuration statements
VFLUID.F	-	Fluid velocity profile required by cable model

Where no changes are to be made to Fortran source files, the object files on M228 may be used. If changes are to be made, the altered file should be compiled as shown below for CHKUPR.F:

```
:FORTRAN CHKUPR +F66 +SYM +XREF -OPT
ELXSI FORTRAN 4.3a           04/08/86     10:31:21
      0 errors in CHKUPR
  compilation time: 0.4 CPU seconds
  lines per minute: 2987
  real time:      27 seconds
  % CPU= 1
      23 lines in this compilation
  Total errors in this compilation: 0
  :
```

The modelling program object files are first bound using the shellfile BINDBOMMPLIB[2] to form library object files BOMMP.LIB.O and DUSER.LIB.O. The listing and execution of BINDBOMMPLIB is as follows:

---

1 This module is not currently operational on the Elxsi computer.

2 If BOMMP were to be used as a stand alone simulation program, the shellfile BINDBOMMP should be used. The listing and execution is as follows:

```
:LIST BINDBOMMP
- - SHELLFILE TO BIND FILES NECESSARY FOR CREATING BOMMP
ECHO :BIND MAIN2,CSMPA,CSMPB,CSMPC,INTEG,DUSER,FCHECK,CHKUPR,PTIME,bfile=BOMMP
BIND MAIN2 CSMPA CSMPB CSMPC INTEG DUSER FCHECK CHKUPR PTIME bfile=BOMMP
:BINDBOMMP
:BIND MAIN2 CSMPA CSMPB CSMPC INTEG DUSER FCHECK CHKUPR PTIME bfile=BOMMP
```

```
:LIST BINDBOMMPLIB
- - Shellfile to create library files necessary for Sea King Math Model
 ECHO :MAKELIB MAIN2,CSMPA,CSMPB,CSMPC,INTEG,FCHECK,CHKUPR,PTIME,lfile=BOMMP
 MAKELIB MAIN2 CSMPA CSMPB CSMPC INTEG FCHECK CHKUPR PTIME lfile=BOMMP
 ECHO :MAKELIB DUSER
 MAKELIB DUSER
:
:BINDBOMMPLIB
:MAKELIB MAIN2 CSMPA CSMPB CSMPC INTEG FCHECK CHKUPR PTIME lfile=BOMMP
:MAKELIB DUSER
:
```

The object files for the Sea King component modules, together with the above library object files are then bound using the shellfile BINDSEAKING, the listing and execution of which is as follows:

```
:LIST BINDSEAKING
ECHO :BIND BOMMP.LIB,SKA86,BLADIN,SKC83,CABLE,CABGEN,VFLUID, &
     SKS86,MJW6,PILOT,LIBFILES=DUSER,bfile=SEAKING86
BIND BOMMP.LIB,SKA86,BLADIN,SKC83,CABLE,CABGEN,VFLUID, &
     SKS86,MJW6,PILOT LIBFILES=DUSER bfile=SEAKING86
:
:BINDSEAKING
:BIND BOMMP.LIB SKA86 BLADIN SKC83 CABLE CABGEN VFLUID SKS86 MJW6 PILOT
LIBFILES=DUSER bfile=SEAKING86
```

5. RUNNING THE SEA KING MODEL

5.1 Standard Input Files

Whenever the model is run, the following three files, examples of which are on tape M228, are required as input:

BOMMP.IN	-	Non-interactive command file for BOMMP
DATA.HEL	-	Helicopter input data, mainly in NAMELIST form
?????.MOD	-	Helicopter model information in form of configuration, parameter, and function statements - must have 5 character name with .MOD extension

File BOMMP.IN is shown below:

```
:LIST BOMMP.IN
 LOG2:19ASW_I
 CON
 PAR
 FUN
 MAN
:
```

The CONfiguration, PARameter, and FUNction commands cause the configuration, parameter, and function statements to be read from the model input file, which is

19ASW.MOD in this case. The MANual command returns from non-interactive to interactive (i.e. manual) control and allows further changes to be made to the model statements before integration and output parameters are specified. These can all be included in the file BOMMP.IN when running completely non-interactively, e.g. in batch, provided the MANual command is removed.

The following three helicopter input data files are also available on tape M228, the required one of which should be renamed DATA.HEL before running SEAKING86:

19200.HEL	-	19200 lb AUW (see Appendix B)
17800.HEL	-	17800 lb AUW
16600.HEL	-	16600 lb AUW

For the above files, there are the following corresponding model files for ASW mode:

19ASW.MOD	-	19200 lb AUW at hover (see Appendix C)
17AS8.MOD	-	17800 lb AUW at 88 kn
16ASW.MOD	-	16600 lb AUW at hover

As well as being used directly with SEAKING86, these files may be converted, using the program SKMODE, to a form suitable for either ASE or pilot mode (see Section 5.3).

5.2 Trimming in ASW mode

The achievement of steady conditions, with all time derivatives equal to zero, is defined to be trimmed flight. Because it is generally desirable to begin any manoeuvre from this condition, the model is run first in ASW mode for the specified flight parameters, thus allowing the Systems component model to 'fly to trim'. An example of this is now given.

The following flight parameters are assumed:

$$\text{Aircraft AUW} = 18500 \text{ lb}$$
$$\text{Aircraft forward velocity} = 40 \text{ kn}$$

From M228, the following files are retrieved and edited as indicated:

BOMMP.IN	-	Unchanged
19ASW.MOD	-	Unchanged
19200.HEL	-	Rename to DATA.HEL, edit parameters RHOA, SPSND, GAMMA, GAMMAT, HMASS, A, B, CC, and HR

For sea-level, ISA conditions assumed,

$$\text{Air density, RHOA} = 0.002377 \text{ slug/ft}^3$$
$$\text{Speed of sound, SPSND} = 1116.45 \text{ ft/s}$$

If density and speed of sound are required for a given atmospheric condition, the program ATMOS, on tape M228, may be used (see Appendix D).

From Appendix B, where RHOA = 0.002199 slug/ft^3,

$$\text{Main rotor Lock number, GAMMA} = 9.95$$
$$\text{Tail rotor Lock number, GAMMAT} = 4.72$$

Since Lock number is proportional to air density, then for RHOA = 0.002377 slug/ft^3,

$$\text{GAMMA} = 10.76$$
$$\text{GAMMAT} = 5.10$$

Given an AUW of 18500 lb,

$$\text{Helicopter mass, HMASS} = \frac{18500}{32.2} = 575 \text{ slugs}$$

and from Appendix E,

$$\text{Roll 2nd moment of inertia, A} = 14275 \text{ slug ft}^2$$
$$\text{Pitch 2nd moment of inertia, B} = 48375 \text{ slug ft}^2$$
$$\text{Yaw 2nd moment of inertia, CC} = 39150 \text{ slug ft}^2$$

Before running SEAKING86, the vertical and longitudinal aircraft centre of gravity (c.g.) positions, CGz and CGx respectively, must be calculated for the new AUW of 18500 lb. These positions are defined as

$$\text{CGz} = (\text{c.g. water line})$$
$$\text{CGx} = (\text{c.g. fuselage station}) - (\text{datum fuselage station})$$

where water lines and fuselage stations (in inches) are shown in Appendix F. The model requires the c.g. positions to be input in the form of parameters HR (see Namelist 'AER' of data file in Appendix B) and XCH (Blk 252 in model file - see Appendix C). HR (in feet) is the vertical displacement of the rotor hub (water line 232) above the c.g. and XCH (in feet) is the longitudinal displacement of the c.g. forward of the datum (fuselage station 267.4 - see loading table for the ASW role, from Ref. 14, in Appendix G), i.e.

$$\text{HR} = \frac{232 - \text{CGz}}{12}$$

$$\text{XCH} = -\frac{\text{CGx}}{12}$$

For an AUW of 18500 lb, CGz is estimated by interpolating data supplied by Westland Helicopters Limited, shown in Table 1:

TABLE 1
Vertical Centre of Gravity Position, CGz

AUW (lb)	CGz (inches)
15000	155
19200	143

$$CG_z = 155 - \left[(155 - 143) \times \left(\frac{18500 - 15000}{19200 - 15000} \right) \right]$$

$$= 145 \text{ inches}$$

$$h_R = \left(\frac{232 - 145}{12} \right) = 7.2 \text{ ft}$$

The Sea King Operating Data Manual (Ref. 14) provides loading tables for each of the major aircraft roles (e.g. ASW, troop transport), which may be used to calculate CGx for a given AUW. The loading table for the primary role (i.e. ASW with 2 torpedoes) is included here as Appendix G. The table gives a breakdown of the weight and corresponding pitching moment about the datum (fuselage station 267.4), for each item of role equipment and for the fuel as it is distributed between the forward, centre, and aft fuel tanks (while filling the aircraft, and also as fuel is used); below each component is the cumulative effect of all preceding components. CGx may thus be calculated by taking the total pitching moment and dividing it by the AUW.

For this example, it is assumed the aircraft is configured as for the flight trials (Ref. 12) i.e. ASW role, less two torpedoes, fitted with flight data acquisition package. Using known weights and positions of the data acquisition package and two observers measured during the flight trials,

Aircraft weight with two crew and two observers, less fuel =	14800 lb
Moment about datum for data acquisition package =	- 6160 lb in
Moment about datum for two observers =	- 31000 lb in
Moment of Sea King (less 2 torpedoes) about datum =	+ 43687 lb in
Aircraft moment less fuel = 43687 - 6160 - 31000 =	+ 6527 lb in.
Fuel weight = 18500 - 14800 =	3700 lb

From the fuel usage section of Appendix G, 3700 lb of fuel is distributed amongst the fuel tanks in the sequence shown in Table 2 (reading from bottom to top in loading table). The net distribution in each tank and the c.g. position aft of the datum is then given in Table 3, from which,

Moment due to fuel = 1700 x (-52.1) + 687 x (-3.7) + 1313 x (49.9) = - 25593 lb in

Adding this moment to the 'aircraft moment less fuel',

Total aircraft moment = 6527 - 25593 = - 19066 lb in

TABLE 2
Sequence of Fuel Distribution

Tank	Weight of fuel (lb)	Cumulative total (lb)
Aft	1208	1208
Forward	1208	2416
Centre	456	2872
Forward	492	3364
Centre	231	3595
Aft	105*	3700

* Balance of fuel (< 1152 lb)

TABLE 3
Net Fuel Distribution

Tank	Weight of fuel (lb)	C.g. aft of datum (inches)*
Forward	1208 + 492 = 1700	(31468)/(-604) = - 52.1
Centre	456 + 231 = 687	(1040)/(-281) = - 3.7
Aft	1208 + 105 = 1313	(- 57485)/(-1152) = 49.9

* Equals $\frac{\text{moment}}{\text{weight}}$ from any case of each tank in loading table of Appendix G

Thus

$$CGx = \frac{\text{total aircraft moment}}{\text{AUW}} = -\frac{19066}{18500} = -1.03 \text{ inches}$$

$$XCH = -\frac{CGx}{12} = 0.09 \text{ ft}$$

The model is now ready to be run. Note that the commands TIT, PAR, and FUN are used interactively to read in modifications to statements (such as the value of XCH), already read in non-interactively through the command lines in BOMMP.IN.

```
:SEAKING86
MAX BLK NO. = 500

MAX NO. OF: I & T1 BLKS, U BLKS, F BLKS = 100,25,25

SEA KING - HOVER - 3000 ft - ASW MODE - 19200 lb AUW
*TIT
TITLE (LIMIT 60 CHRS)
SEA KING - 40 kn - ISA, SEA-LEVEL - ASW MODE - 18500 lb AUW
```

```
*PAR
PARAMETERS :

BLK, P1, P2, P3
252,0.09                                    Aircraft c.g. position - XCH (ft)

*FUN
FUNCTIONS :

BLK NO. = 51                                Set aircraft forward velocity (ft/s)
COORD PAIRS :

0,0
COORD PAIR (    .0000E+00,      .0000E+00) DELETED
500,67.512                                  Note:  40 kn = 67.512 ft/s
COORD PAIR (  5.0000E+02,      .0000E+00) DELETED
700,67.512

BLK NO. = 80                                Set aircraft height (ft)
COORD PAIRS :

0,3000
COORD PAIR (    .0000E+00,     3.0000E+03) DELETED
500,200
COORD PAIR (  5.0000E+02,     3.0000E+03) DELETED
700,200

BLK NO. =
MODEL COMPLETE

*INT
INTEGN PARAMS; LOWER, UPPER, INTERVAL =  0,700,0.02
*OUT
O/P BLKS
A
O/P PARAMS; % CHANGE REQRD, INTERVAL =  0.0001,100
*LOG3:TRIM1_M
MODEL O/P TO     LOG3:TRIM1.MOD

*STO
TRIM1.MOD    NOT ON DSK

CON, PAR, FUN, OR ALL : A
*LOG2:TRIM1_I
MODEL I/P FROM    LOG2:TRIM1.MOD
```

```
*LOG1:TRIM1_O
BLOCK O/P TO    LOG1:TRIM1.DAT

*GOE
TRIM1.DAT    NOT ON DSK
** RUNNING **
TRIM1.HEL    NOT ON DSK

  (s)     (Ft)   (Ft/m)    (Knots)
  Time     Alt   RoC/D   Speed  Slip  %Torq
    .0   3000.     -.3     -.0  -.00     90.
%Colctv         %Cyclic
                F-A      Lat
 -94.31      -25.06    -2.49
A.S.E. Channels :
PITCH - On
ROLL - On
YAW - On
ALT HOLD - RAD

A.S.W. Mode :
 TRAN
[Cyclic Trim -  ENGE]
    .0   3000..    -.3     -.0  -.00     90.
   1.0   3000.   -48.8     -.1   .12     80.
   2.0   2998.  -198.1     -.2   .23     73.
   3.0   2994.  -292.0     -.1   .17     77.
   4.0   2989.  -323.0      .0   .19     79.
   5.0   2983.  -316.5      .3   .26     82.
     .
     .
     .
     .
 698.0    200.     -.0    40.0  -.00     44.
 699.0    200.      .0    40.0  -.00     44.
 700.0    200.     -.0    40.0   .00     44.
RUN CPU TIME :   13 Min. 21.53 Sec.

*RET
*STO
TRIM1.MOD    NOT ON DSK
CON, PAR, FUN, OR ALL :  A
*EXI
Fortran program executed STOP statement 0
:
```

In the example above, model output was displayed on the terminal screen every 1 second. If desired, the user may adjust the output time interval, which is the first parameter of Blk 240. If no output to the screen is desired the parameter of Blk 99 is set to zero.

After running the model, the following five files are created:

FROMAN.OUT	-	Record of user input commands
DATA.CHD	-	Output of data read from DATA.HEL
TRIM1.CHR	-	Debugging information
TRIM1.DAT	-	Output data - used as input to TRANS
TRIM1.MOD	-	Model file

For multiple runs, FROMAN.OUT may be concatenated with BOMMP.IN (after deleting the MANual command), and used to run the model completely non-interactively. DATA.CHD (see Appendix H) echoes the data read in from DATA.HEL. TRIM1.CHR contains debugging information if the DEBug command is used; otherwise it is empty. TRIM1.DAT is the output data from the model run, and is used as input to program TRANS in order to obtain tabular or plotted results. The example below on using TRANS prints the pitch attitude (Blk 282) and torque (Blk 212) to the screen.

```
:TRANS
[TRANS version date 11-MAR-86]

I/P FILENAME = TRIM1
SEA KING - 40 kn - ISA, SEA-LEVEL - ASW MODE - 18500 lb AUW

I/P FILE RECORDED ON 12-Jan-87 AT 16:04:39

INTEGN INT = .0000E+00; RUN CPU TIME = 13 MIN 21.53 SEC.

TIME FROM  .0000E+00 TO 7.0000E+02 IN STEPS OF 1.0000E+02

*TIM
TIME PARAMS; LOWER, UPPER, INTERVAL = 0,700,700
*PRC
PRINTING IN COLUMNS :

BLKS
282,212

IS O/P TO TTY REQRD : Y
*GOE
** RUNNING **
   Time    Blk#282  Blk#212

   .00E+00  4.35E+00 8.99E+00
  7.00E+00  4.94E+00 4.43E+00
*EXI
:
```

As a consequence of the RETain and STOre commands entered prior to terminating the above run of SEAKING86, the file TRIM1.MOD represents the updated model with integrator initial conditions set at terminating values. The file can therefore be used in this case, following minor modifications, as the starting point for trimmed flight at 18500 lb AUW, 40 kn (67.512 ft/s) forward speed, and 200 ft altitude (nominally sea-level for atmospheric conditions). The modifications required are to the aircraft set forward speed (Blk 51) and set height (Blk 80) function blocks, which need to be set to maintain the aircraft at constant velocity and height. This may be done either interactively or simply by editing TRIM1.MOD appropriately to include in the FUNctions section:

```
51
.0000E+00     6.7512E+01
5.0000E+02    6.7512E+01

80
.0000E+00     2.0000E+02
5.0000E+02    2.0000E+02
```

5.3 Standard Manoeuvres

The Sea King Model may be flown in any of three standard modes, i.e. ASW, ASE, or pilot mode. In ASW mode, the flight control system flies the aircraft, stabilizing it in roll, pitch,and yaw, while holding a given heading and altitude. In ASE mode, the pilot flies the aircraft while the flight control system stabilizes the aircraft in roll, pitch, and yaw. In pilot mode, the pilot flies the aircraft with no input from the flight control system.

In the previous section, it was shown how to obtain an 'ASW' model file, starting from one of the master files. However, this model file has many parameters which have deviated from a zero value during the trimming procedure. A program called SKMODE is available to make these values zero and/or change the mode from ASW to ASE or pilot mode. An example is shown below on how to use SKMODE to obtain model files for each of the three modes, creating model files 18ASW.MOD, 18ASE.MOD, and 18PIL.MOD.

```
:SKMODE
 INPUT FILE (ASW MODE .MOD FILE) : TRIM1
 MODEL FILE REQUIRED (ASW,ASE,PIL OR ALL) : ALL
 OUTPUT FILE (ASW MODE .MOD FILE) : 18ASW
 ??ASW.MOD TITLE :SEA KING - 40 kn - ISA, SEA-LEVEL - ASW MODE - 18500 lb AUW
 OUTPUT FILE (ASE MODE .MOD FILE) : 18ASE
 ??ASE.MOD TITLE :SEA KING - 40 kn - ISA, SEA-LEVEL - ASE MODE - 18500 lb AUW
 OUTPUT FILE (PILOT MODE .MOD FILE) : 18PIL
 ??PIL.MOD TITLE :SEA KING - 40 kn - ISA,SEA-LEVEL - PILOT MODE - 18500 lb AUW
:
```

Examples of how to use these model files are shown in the following sections.

5.3.1 ASW Mode

In Section 5.2, the ASW mode was used to 'fly to trim', ramping the aircraft set forward speed and height functions over a 500 second time interval from 0 to 40 kn and 3000 to 200 ft, and then over a further 200 second interval to stabilize the trim. It can be

seen from Figure 1, which shows the timing of the flight control system in ASW mode, that this trim case does not represent a realistic segment of a true ASW manoeuvre. The example now given for the ASW mode represents the 'transition down' phase and is realistic.

Firstly, BOMMP.IN is edited, replacing 19ASW with 18ASW:

```
:LIST BOMMP.IN
LOG2:18ASW_I
CON
PAR
FUN
MAN
:
```

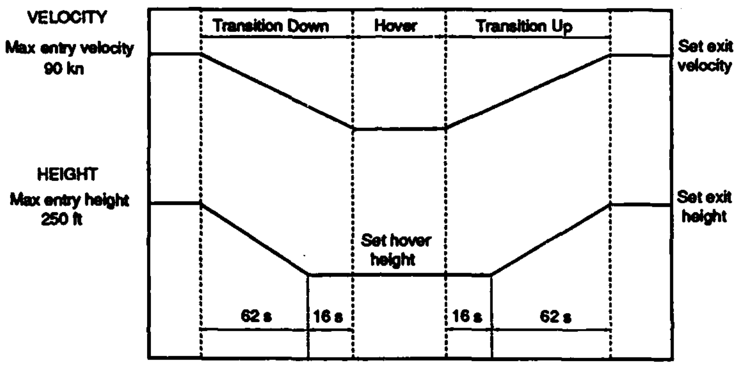


Fig. 1 Timing of Flight Control System in ASW Mode

Assuming the aircraft begins the transition 1 s after beginning the run, the set forward velocity and height function blocks in the model file 18ASW.MOD should be modified as shown directly below, either interactively when running SEAKING86 (as done in the example below) or by editing:

```
51
.0000E+00    6.7512E+01
1.0000E+00   6.7512E+01
7.9000E+01   .0000E+00
5.0000E+02   .0000E+00

80
.0000E+00    2.0000E+02
1.0000E+00   2.0000E+02
6.3000E+01   4.0000E+01
5.0000E+02   4.0000E+01
```

The model is now run:

```
:SEAKING86
MAX BLK NO. = 500

MAX NO. OF: I & T1 BLKS, U BLKS, F BLKS = 100,25,25

SEA KING - 40 kn - ISA, SEA-LEVEL - ASW MODE - 18500 lb AUW
*TIT
TITLE (LIMIT 60 CHRS)
SEA KING - TRANSITION DOWN - ASW MODE - 18500 lb AUW
*FUN
FUNCTIONS :

BLK NO. = 51
COORD PAIRS :

0,67.512
COORD PAIR (  .0000E+00,     6.7512E+01) DELETED
1,67.512
79,0
500,0
COORD PAIR ( 5.0000E+02,     6.7512E+01) DELETED

BLK NO. = 80
COORD PAIRS :

0,200
COORD PAIR (  .0000E+00,     2.0000E+02) DELETED
1,200
63,40
500,40
COORD PAIR ( 5.0000E+02,     2.0000E+02) DELETED

BLK NO. =
MODEL COMPLETE

*INT
INTEGN PARAMS; LOWER, UPPER, INTERVAL = 0,90,0.02
*OUT
O/P BLKS
A
O/P PARAMS; % CHANGE REQRD, INTERVAL = 0.0001,0.5
*LOG3:TRDWN_M
MODEL O/P TO    LOG3:TRDWN.MOD

*STO
```

```
TRDWN.MOD     NOT ON DSK

CON, PAR, FUN, OR ALL : A
*LOG2:TRDWN_I
MODEL I/P FROM     LOG2:TRDWN.MOD

*LOG1:TRDWN_O
BLOCK O/P TO     LOG1:TRDWN.DAT

*GOE
TRDWN.DAT     NOT ON DSK

** RUNNING **
TRDWN.HEL     NOT ON DSK

  (s)     (Ft)   (Ft/m)     (Knots)
  Time     Alt   RoC/D  Speed  Slip  %Torq
    .0    200.    -.0   40.0    .00    44.
%Colctv        %Cyclic
               F-A      Lat
-120.86      -7.42     -5.70
A.S.E. Channels :
PITCH - On
ROLL - On
YAW - On
ALT HOLD - RAD

A.S.W. Mode :
 TRAN
[Cyclic Trim -  ENGE]
    .0    200.    -.0   40.0    .00    44.
   1.0    200.    -.1   40.0   -.00    44.
   2.0    200.  -49.9   39.9   -.10    43.
   3.0    198.  -99.9   39.8    .12    39.
   4.0    196. -125.1   39.7    .30    40.
   5.0    194. -132.8   39.5    .27    39.
    .
    .
    .
  88.0     40.   -3.2   -1.9   -.45    84.
  89.0     40.   -2.7   -1.9   -.45    84.
  90.0     40.   -2.3   -2.0   -.43    84.
RUN CPU TIME :    1 Min. 52.46 Sec.
*EXI
Fortran program executed STOP statement 0
:
```

As can be seen above, after 90 seconds the aircraft has completed the transition but is not yet in a trimmed hover. This could be achieved by running for a further period (e.g. 50 seconds).

5.3.2 ASE and Pilot Modes

Flying the model in ASE or pilot mode is much more difficult than ASW mode, because the user must input commands similar to those input by the pilot on a real Sea King. Since the user usually has had no helicopter flying experience and the model does not give good cues, it is difficult to 'fly' the model in ASE mode, and extremely difficult in pilot mode. However, the model may be more easily 'flown' in these modes by reading control inputs obtained from flight data (see Ref. 12). When flight data is not used, the method used to 'fly' the model is the same for both ASE and pilot modes.

The method used is a trial-and-error one, where the control inputs, namely the cyclic stick positions (Blks 56 and 60), collective stick position (Blk 81), and the pedal position (Blk 72), are changed from integrator to function blocks. The position of each control is then input at specific times and the model is run. The results can then be observed and the control positions adjusted to give the desired results.

In the Sea King, a stick 'beeping' facility is used to trim the aircraft when flying in ASE mode, this being the recommended mode for normal flight. In the model, this facility may be used by first changing the following switches into function blocks:

Blk 77	-	S FWD
Blk 78	-	S AFT
Blk 67	-	S STBD
Blk 68	-	S PORT

The model can then be flown with small inputs via the beeping. When any particular block has a value of one, the beeping is turned on, while a value of zero turns the beeping off. For more information on the aircraft systems see Ref. 7.

6. CONCLUDING REMARKS

One of the consequences of taking a number of years to develop and then validate a useful mathematical model such as the Sea King one, is that by the time the process is concluded, the software methodology is out-of-date. Greater priority is then likely to be given to gaining a return on the investment in the form of practical applications of the model, rather than in rewriting the code. The simulation language CSMP-10(ARL) was developed in-house at a time prior to other more suitable languages such as ACSL becoming available at economic rates. The decision to continue using the model within the framework of a now dated language, and to transfer the model from the obsolete DEC System 10 to the Elxsi 6400, has necessitated adequate documentation in the form of these user manuals.

REFERENCES

1. Gilbert, N.E. and Nankivell, P.G., "The Simulation Language CSMP-10(ARL)," *ARL Aero Note 362*, May 1976.

2. Gilbert, N.E. and Nankivell, P.G., "Further Information for Users of the Simulation Language CSMP-10(ARL)," *ARL Aero Note 375*, May 1978.

3. Nankivell, P.G. and Gilbert, N.E., "A General Purpose Output Program for Use in Simulation," *ARL Aero Note 367*, December 1976.

4. Guy, C.R., Williams, M.J., and Gilbert, N.E., "Sea King Anti-Submarine Warfare Helicopter Mathematical Model," *Mech. Engg. Trans., I.E. Aust.*, Vol. ME7, pp. 23-29, April 1982.

5. Guy, C.R., Williams, M.J., and Gilbert, N.E., "A Mathematical Model of the Sea King Mk 50 Helicopter in the ASW Role," *ARL Aero Report 156*, June 1981.

6. Williams, M.J. and Arney, A.M. "A Mathematical Model of the Sea King Mk 50 Helicopter Aerodynamics and Kinematics," *ARL Aero Tech Memo 379*, June 1986.

7. Guy, C.R. "Sea King Mk 50 Helicopter/Sonar Dynamics Study: A Simplified Control Systems Mathematical Model," *ARL Aero Report 152*, February 1979.

8. Guy, C.R. "Sea King Mk 50 Flight Control System: A Mathematical Model of the Flying Controls," *ARL Aero Note 388*, February 1979.

9. Guy, C.R. "Sea King Mk 50 Flight Control System: A Mathematical Model of the AFCS (Autostabilizer/Autopilot Model)," *ARL Aero Note 389*, February 1979.

10. Guy, C.R. "Sea King Mk 50 Flight Control System: A Mathematical Model of the AFCS (ASW Mode)," *ARL Aero Note 393*, June 1979.

11. Gilbert, N.E. "A Mathematical Model of the Dynamics of the Cable and Sonar Transducer for a Sea King Mk 50 Helicopter," (to be published).

12. Arney, A.M. and Gilbert, N.E., "A User's Manual for the ARL Mathematical Model of the Sea King Mk 50 Helicopter: Part II - Use with ARL Flight Data," *ARL Aero Tech Memo 407*, October 1988.

13. Gilbert, N.E. and Arney, A.M. "A User's Manual for the ARL Mathematical Model of the Sea King Mk 50 Helicopter : Part III - Use of Dunking Sonar Model," *ARL Aero Tech Memo* (to be published).

14. "Operating Data Manual - Sea King Mk 50," *A.P. (RAN) 300-8-2*.

APPENDIX A
Files on Tape M228

The following files are on Sequence 1 of magnetic tape M228, under the pathname 'SEAKINGMASTERFILES':

/atmos
/atmos.f
/atmos.o
/ATMOS.OUT
/BINDBOMMP
/BINDBOMMPLIB
/BINDSEAKING
/bladin.f
/bladin.o
/BOMMP
/BOMMP.LIB.O
/cabgen.f
/cabgen.o
/cable.f
/cable.o
/CablePlot
/CablePlot/BINDCABGRA
/CablePlot/CABGRA
/CablePlot/CABGRA.F
/CablePlot/cabgra.o
/CablePlot/cabplot
/CablePlot/cabxtr.f
/CablePlot/cabxtr.o
/CablePlot/CUBE.F
/CablePlot/CUBE.o
/CablePlot/NEGSK.GRA
/CablePlot/PLTCAB.F
/CablePlot/PLTCAB.o
/CablePlot/SONAR.F
/CablePlot/SONAR.o
/chkupr.f
/chkupr.o
/csmpa.f
/csmpa.o
/csmpb.f
/csmpb.o
/csmpc.f
/csmpc.o
/duser.f
/DUSER.lib.o
/duser.o
/fcheck.f
/fcheck.o
/integ.f
/integ.o
/main2.f
/main2.o
/mjw6.f
/mjw6.o
/pilot.f
/pilot.o
/ptime.f
/ptime.o
/READTAPE
/SEAKING86
/SKa86.f
/SKa86.o
/SKc83.f
/SKc83.o
/SKmode
/SKmode.f
/SKmode.o
/SKs86.f
/SKs86.o
/vfluid.f
/vfluid.o

The following files are on Sequence 2 of magnetic tape M228, under the pathname 'seakingfiles':

/16600.HEL
/16ASW.MOD
/17800.HEL
/17AS8.MOD
/19200.HEL
/19ASW.MOD
/80.SCA
/BOMMP.IN
/DATA.HEL
/HOVER.SCA
/PLOT
/REDATA
/Refine
/Refine/BINDLABCAL
/Refine/BINDREFINE
/Refine/CAL86
/Refine/ChkUpr.f
/Refine/ChkUpr.o
/Refine/Ding.f
/Refine/Ding.o
/Refine/LabCal
/Refine/LabCal.f
/Refine/LabCal.o
/Refine/NotchFilter.f
/Refine/NotchFilter.o
/Refine/PreNotch.f
/Refine/PreNotch.o
/Refine/R1.f
/Refine/R1.o
/Refine/R2.f
/Refine/R2.o
/Refine/R3.f
/Refine/R3.o
/Refine/R4.f
/Refine/R4.o
/Refine/R5.f
/Refine/R5.o
/Refine/R6.f
/Refine/R6.o
/Refine/REFIN
/Refine/REFINE
/Refine/REFINMASTER
/Refine/REFINPSIREPLACED
/Refine/Rename.f
/Refine/Rename.o
/Refine/Rextra.f
/Refine/Rextra.o
/Refine/TSub87.f
/Refine/TSub87.o
/Trans
/Trans/BINDTRANS
/Trans/ChkUpr.f
/Trans/ChkUpr.l
/Trans/ChkUpr.o
/Trans/Extra.f
/Trans/Extra.l
/Trans/Extra.o
/Trans/Rname.f
/Trans/Rname.l
/Trans/Rname.o
/Trans/TRANS
/Trans/TRANS1b.f
/Trans/TRANS1b.l
/Trans/TRANS1b.o
/Trans/TRANS2b.f
/Trans/TRANS2b.l
/Trans/TRANS2b.o
/TRANS.BLK
/TRANS.LAB

APPENDIX B
Data File 19200.Hel

```
 $AER
G=32.2, RHOA=0.002199, RHOW=1.984, SPSND=1105.26
HMASS=596, A=14162, B=49282, CC=39776, EIT=10800
ONEMZE=0.823, THETA1=-0.139, GAMMA=9.950, DELTA=0.012, R2=31,ZETA0=0.0339, SIGMA=0.078
THSH=-0.0698, BLMN=5, EKAPPA=0.305, EK3=0.08, EK4=0.001903, EK5=0.16
ONEMZT=0.77, GAMMAT=4.72, SIGMAT=0.224, RT=5.21, BLTL=6
FGLOSS=1.04, RPMSET=209, SHPMAX=2778, GRRAT=6.127
EKI=2, EI=0, STH=19.4, STV=21.5, STRF=0, SX=102, SY=415, SZ=318
SMALLA=7.20, EKTH=1.0, ALTHS=0.192, ALTVS=0.192, ATH=3.5, ATV=4.35
CDXF=0.343, CDYF=0.77, CDZF=0.7, CDTH=1.18, CDTV=1.86
ALPHAL=-0.0873, ALPHAD=-0.1047, EFF4=0.5, SCLAL=225, SCDAL=230, SCMBOD=5000
SCDUO=0, SCDWEP=0, SCMUO=0, SCMWEP=0
HR=7.4, HROTO=15.5, HT=4.75, ELT=36.5, ELTH=36.3, ELTV=34.4,
HTV=2.5, DTH=3.0, HF=1.5
KIH=1.10, KIHTR=1.4,KA1=1.0,
NTBL1=12, NTBL2=12, NTBL3=10, NTBL4=6
 $

TBL1  -  'FORMAT(10E)'  -  NTBL1 VALUES
0, 3.29, 0.35, 3.29, 0.79, 2.16, 1.05, 1.95, 1.22, 1.65
1.57, 1.27

TBL2  -  'FORMAT(10E)'  -  NTBL2 VALUES
-0.1, 0, 0, 0.08, 0.085, 2.35, 0.15, 2.35, 0.30, 0
0.50, 0

TBL3  -  'FORMAT(10E)'  -  NTBL3 VALUES
0, -4, 0.26, -4, 0.44, 0, 1, 5.5, 1.57, 5.5

TBL4  -  'FORMAT(10E)'  -  NTBL4 VALUES
-200, -62112.0, 0, -15528.0, 200, -62112.0

 $CAB
ABALL=0.56, DBALL=1.28, MBALL=4.61, VBALL=1.644
CNCAB=1.2, CFCAB=0.0, DCAB=0.0467, MCAB=0.00686
DFUNL=6.3, ALPHAF=10.75, THEFH=3.65, PHIFH=3.0
SFIRST=6.3, SLAST=5.0, SMID=1.3, SRIGID=200.0, ZTOL=2.0
NL=12, NCXB=32, NCZB=30
 $

SRATIO  -  'FORMAT(10E)'  -  NL-1 VALUES WITH SUM = 1
0.0, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1
0.1

CXBTBL  -  'FORMAT(10E)'  -  NCXB VALUES
0, 0, 35, 1.69, 45, 2.09, 50, 2.21, 55, 2.27
65, 2.27, 70, 2.25, 80, 2.14, 85, 2.13, 105, 2.34
115, 2.36, 120, 2.30, 125, 2.20, 140, 1.67, 160, 0.77
180, 0

CZBTBL  -  'FORMAT(10E)'  -  NCZB VALUES
0, 0.66, 15, 0.77, 25, 0.76, 35, 0.67, 45, 0.52
55, 0.47, 75, 0.12, 95, 0.12, 110, -0.19, 130, -0.55
145, -0.77, 155, -0.86, 165, -0.83, 175, -0.67, 180, -0.66
```

```
 $SYS
CP1=0.7469, CP2=0.37, CP3=0.5, CP4=0.68, CP5=0.003513, CP6=0.000217
CP9=0.0541, CP10=15.31, CP11=0.015, CP12=0.013, CP13=0.00001, CP14=0.0088, CP15=0.00018, CP16=0.154
TP1=0.07, ELAP=0.26915, ELBP=0.02, ELCP=0.3054, CP17=15.3985, CP18=1.0, CP19=0.16
CR1=0.4626, CR2=1.4, CR3=0.2, CR4=0.13, CR5=0.007233, CR6=0.000227
CR9=0.08377, CR10=15.31, CR11=0.0185, CR12=0.018, CR13=0.000014, CR14=0.0047, CR15=0.00048, CR16=0.166
CR17=11.586, CR18=1.0, CR19=0.0694
TR1=0.025, TR2=0.1, TR3=1.0, ELAR=0.26915, ELBR=0.01326, ELCR=0.2909
CY1=3.916, CY2=0.0698, CY3=89.0, CY4=23.35, CY5=4.378, CY6=2.02, CY7=0.3652, CY8=1.0
CY9=0.212, CY10=0.000371, CY11=2.202, CY12=1.0311, CY13=165.9, ELAY=4.0, ELCY=0.3035, ELOY=0.00175
CC1=1.2973, CC2=0.1082, CC3=0.1484, CC4=1.961, CC5=2.438
CC6=0.01064, CC7=30.88, CC8=1.0, CC9=0.221, CC10=0.000561, CC11=100.00
CC12=0.6466, CC13=273.3, CC14=165.9, CC15=0.0, ELAC=4.0, ELOC=0.005077, ELMAX=0.3141, ELMIN=0.0
CC16=30.88, TMP=0.25, TSMP=1.75, TMR=0.25, TSMR=4.1
 $
```

APPENDIX C
Model File 19ASW.Mod

```
CONFIGURATIONS
SEA KING - HOVER - 3000ft - ASW MODE - 19200 lb AUW
  2 I    25      ; PSI HE
  3 I    26      ; THE HE
  4 I    27      ; PHI HE
  5 I    38      ; P HEH
  6 I    39      ; Q HEH
  7 I    40      ; R HEH
  8 I    35      ; U HEH
  9 I    36      ; V HEH
 10 I    37      ; W HEH
 11 I   317      ; OMEGA
 12 I    28      ; X HEE
 13 I    29      ; Y HEE
 14 I    30      ; Z HEE
 23 G    11      ; OMEGA T
 24 F     1      ; V WE
 25 U3  315      ; PSI DOT
 16 UO   25      ; A NORM
 17 UO   25      ; A LAT
 18 UO   25      ; A LONG
 19 UO   25      ; E NU
 20 UO   25      ; AOT
 21 UO   25      ; FNUBRT
 22 UO   25      ; FNUBAR
 26 UO   25      ; THE DOT
 27 UO   25      ; PHI DOT
 28 UO   25      ; U HEE
 29 UO   25      ; V HEE
 30 UO   25      ; W HEE
 31 UO   25      ; FCT
 32 UO   25      ; CT T
 33 UO   25      ; E LAMD T
 34 UO   25      ; E MU T
 35 UO   25      ; U HEH DT
 36 UO   25      ; V HEH DT
 37 UO   25      ; W HEH DT
 38 UO   25      ; P HEH DT
 39 UO   25      ; Q HEH DT
 40 UO   25      ; R HEH DT
 41 UO   25      ; AX H
 42 UO   25      ; AY H
 43 UO   25      ; AZ H
 44 UO   25      ; A0
 45 UO   25      ; XI
 46 UO   25      ; CQH
 48 UO   25      ; A1
 49 UO   25      ; B1
 47 U12   1      ; CHANIN
 50 T1    3      ; AU P IN
 51 F     1      ; U COMM
 52 T1   51      ; U CO SM
 53 U   136          ; S TH STD
 54 T1  154          ; V GVP
 55 T1   35          ; U DT SM
 56 I   125  53  57; THE STK
 57 K                ; S TRM RL
 59 I   133  96      ; PI OUT
 60 I   128  63  57; PHI STK
 61 T1  134          ; PHI INT
 62 T1    4          ; AU R IN
 63 U   141          ; S PH STD
 65 T1   36          ; V DT SM
 66 T1  153          ; V GVR
 67 K                ; S STBD
 68 K                ; S PORT
 69 I   135  96      ; RI OUT
 70 K                ; PSI REF
 71 I   110  96      ; PSI INT
 72 I   138  73  74; D PEDALS
 73 U   139          ; S D PEDD
 74 K                ; S PEDLS
 75 I   140  96      ; D AUX Y
 76 K                ; PSI TRM
 77 K                ; S FWD
 78 K                ; S AFT
 79 K                ; S YAW PPR
 80 F     1          ; H COMM
 81 I   142  86  87; THE C ST
 82 T1  118          ; ZH SM
 83 T1   80          ; HC SM
 84 I   113  96      ; Z ERI
 85 I   143  96      ; D AUX C
 86 U   144          ; SC STD
 87 K                ; ST CS PL
 88 K                ; PIT TRM
 89 K                ; ROL TRM
 90 K                ; S BLADE
 91 K                ; S DOP
 92 K                ; S CAB
 94 K                ; S BARA
 95 K                ; S RADA
 96 K                ; HOLD
 97 K                ; THE TRM
 98 K                ; PHI TRM
 99 K                ; S CONTROL
100 U2  160          ; U ERR
101 UO  100          ; AUTO PL
102 UO  100          ; DOP P
103 UO  100          ; CAB P
104 UO  100          ; OLD B1S
105 UO  100          ; ASW R
```

```
106 U0  100        ; AUTO RL
107 U0  100        ;  DOP R
108 U0  100        ;  CAB R
109 U0  100        ; OLD A1S
110 U0  100        ;  PSI ID
111 U0  100        ; AUTO YL
112 U0  100        ; THETA T
113 U0  100        ;  HT INT
114 U0  100        ; AUTO CL
115 U0  100        ;  RAD A
116 U0  100        ; OLD TH C
117 U0  100        ;  ASW P
118 U0  100        ;  ZB ERR
119 U0  100        ; S AUTO C
121 U0  100        ; S AUTO P
122 U0  100        ; S AUTO R
123 U0  100        ; S AUTO Y
124 U0  100        ; S MULT P
125 U0  100        ; THE TDT
126 U0  100        ; S FWD H
127 U0  100        ; S AFT H
128 U0  100        ; PHI TDT
129 U0  100        ; S STBD H
130 U0  100        ; S PORT H
131 U0  100        ; THE ERT
132 U0  100        ; PHI ERT
133 U0  100        ;  PI IN
134 U0  100        ;  PHI TS
135 U0  100        ;  RI IN
136 U0  100        ; S TH ST
137 U0  100        ; S MULT R
138 U0  100        ; D PED DT
139 U0  100        ; S D PED
140 U0  100        ; D AY DT
141 U0  100        ; S PH ST
142 U0  100        ; TH CS D
143 U0  100        ; D AC DT
144 U0  100        ;  SC ST
145 U0  100        ; D XB DED
146 U0  100        ; D SPR C
147 U0  100        ;  BAR A
148 U0  100        ;  CLU A
149 U0  100        ;  Z REF
150 U0  100        ; THE CLU
151 U0  100        ;  CLU ST
152 U0  100        ;  HT PRP
153 U0  100        ; V GR IN
154 U0  100        ; V GP IN
158 F     1        ;B DPTH COM
159 F     1        ;C MODE COM
160 U4   25 158  14;CAB LENGTH
161 U0  160        ; CAB VEL
162 U0  160        ; CAB ACCEL
163 U0  160        ;M BALL CAB
164 U0  160        ; THE CAB
165 U0  160        ; PHI CAB
```

```
166 U0  160        ;  THE CH
167 U0  160        ;  PHI CH
168 U0  160        ; THE FUN
169 U0  160        ; PHI FUN
170 U0  160        ; TENSN HEL
171 U0  160        ;   TX H
172 U0  160        ;   TY H
173 U0  160        ;   TZ H
174 U0  160        ;TENSN BALL
175 U0  160        ; THE BALL
176 U0  160        ; PHI BALL
177 U0  160        ;  U BALL
178 U0  160        ;  V BALL
179 U0  160        ;  W BALL
183 U6   25        ; TORQ LD
184 U0  183        ;  X CH H
185 U0  183        ;    XF
186 U0  183        ;    X
187 U0  183        ;  Z CT H
188 U0  183        ;    ZF
189 U0  183        ;   Z TH
190 U0  183        ;    Z
191 U0  183        ;  EM MH
192 U0  183        ;  EM FT
193 U0  183        ;  EM QT
194 U0  183        ;  EM HH
195 U0  183        ;  EM HS
196 U0  183        ;  EM TH
197 U0  183        ;    EM
198 U0  183        ;  TORQ T
200 U0  183        ;    WI
201 U0  183        ;  ALPHA
202 U0  183        ;   E MU
203 U0  183        ;  E LAMD
204 U0  183        ;    QS
205 U0  183        ;   QST
207 U0  183        ;  HBLDTP
208 U0  183        ;   WEFF
209 U0  183        ;  ALPHTH
210 U0  183        ;  CHIANF
211 U0  183        ;  CHIFA
212 U0  183        ; TORQ PC
213 U0  183        ;  EL YH
214 U0  183        ;  EL TT
215 U0  183        ;  EL LH
216 U0  183        ;  EL FT
217 U0  183        ;  EL TRF
218 U0  183        ; PSI WEF
219 U0  183        ;   A1W
220 U0  183        ;   B1W
221 U0  183        ; ALPHA W
222 U0  183        ;  EF ZED
223 U0  183        ; THETA C
224 U0  183        ;  ELTHM
225 U0  183        ;   EL
226 U0  183        ;  ENTT
```

```
227  UO    183          ;    ENYH
228  UO    183          ;   ENQLG
229  UO    183          ;   ENFUS
230  UO    183          ;   ENTRF
231  UO    183          ;     EN
232  UO    183          ;    BETA
233  UO    183          ;   TORCMP
234  UO    183          ;   TTRCMP
235  T1     19          ; E NU LAG
236  T1    104          ;  B1S LAG
237  T1    109          ;  A1S LAG
240  U10   100   99     ; CONTROL C
241  K                  ; S BLADES
242  O     320          ; B1S UPDAT
243  R     241 242 236;  B1S RLY
244  O     320          ; A1S UPDAT
245  R     241 244 237;  A1S RLY
246  O     320          ;TH T UPDAT
247  R     241 246 112; TH T RLY
248  O     320          ;TH C UPDAT
249  R     241 248 116; TH C RLY
250  K                  ;  W WEE
251  K                  ; PSI WEE
252  K                  ;   XCH
258  K                  ; H HOVER
267  K                  ;  T DOP
269  K                  ;  T BARA
270  K                  ;  T RADA
272  K                  ; T AUTO P
273  K                  ; T AUTO R
274  K                  ; T AUTO Y
275  K                  ; T AUTO C
276  G      56          ; PITCH STK
277  G      60          ; ROLL STK
278  G      81          ; COLL STK
279  G       6          ;PITCH RATE
280  G       5          ; ROLL RATE
281  G       7          ; YAW RATE
282  G       3          ; PITCH ATT
283  G       4          ; ROLL ATT
284  G       2          ; YAW ATT
285  G     201          ;PITCH VANE
286  G     232          ;SSLIP VANE
287  G       8          ; LONG DOPP
288  G       9          ; LAT DOPP
289  G      14          ; RAD ALT
290  G     319          ; ROT RPM
291  G      14          ; BAR ALT
292  G     243          ;    B1S
293  G     245          ;    A1S
294  G     249          ; THETA C
295  G     247          ; THETA T
296  O     294          ; THETA C75
298  K
299  G     278
300  +     298 299      ; RPM REF
301  +    -290 300      ; RPM ERR
302  G     301
303  G     313          ; ERR DIF
304  K                  ;IDLE F FLW
305  +     304 313      ;TOT F FLOW
313  T1    302          ; FUEL FLOW
314  T1    303          ;    ET
315  W     314 303      ;  TRQENG
316  +    -183 315      ; TRQ DIF
317  G     316          ; OMG DOT
319  +     323  11      ;  OMGSH
320  K                  ;  DUMMY
321  K                  ;S PED ENG
322  G       7          ;R HEH ON 3
323  R     321 322     7;ENG R HEH
324  K                  ;  DUMMY
```

PARAMETERS

```
 2 -2.4596E-05
 3  7.5957E-02
 4 -5.7573E-02
 5 -2.3081E-05
 6 -2.2543E-06
 7  4.0773E-05
 8 -4.5318E-04
 9 -2.5422E-03
10  4.0077E-03
11  2.1757E+01
12  4.4524E+04
13 -8.1356E+01
14 -3.0000E+03
16 -3.2054E+01
17  1.8467E+00
18  2.4436E+00
19  4.2206E+01
20  4.9884E-02
21  9.9992E-01
22  1.0001E+00
23  6.1270E+00
26  9.5507E-08
27 -1.9973E-05
28 -1.3721E-04
29 -2.3073E-03
30  4.1698E-03
31  6.4716E-03
32  1.5678E-02
33 -1.2400E-01
34  5.6877E-06
35  1.6713E-04
36 -7.7081E-04
37  2.1744E-04
38 -5.8239E-05
39 -2.7446E-05
40  2.7602E-04
41  1.6713E-04
42 -7.7057E-04
```

43	2.1362E-04		150	2.3895E-01			
44	9.3214E-02		151	-9.1998E-04			
45	1.9266E-01		153	-1.1473E-02			
46	5.1187E-04		154	2.1204E-03			
48	4.6509E-07		184	1.4564E+03			
49	5.8785E-06		185	1.6210E-08			
50	7.5957E-02	7.0000E-02	186	1.4564E+03			
52	4.2039E-44	2.1000E+00	187	-1.9539E+04			
54	-4.4191E-04	1.2400E+01	188	4.3349E+02			
55	3.7602E-06	1.2400E+01	189	1.9258E+00			
56	-7.4250E-02		190	-1.9104E+04			
59	-1.2752E-02		191	-5.7763E+02			
60	-7.3700E-03		192	6.9906E+01			
61	-7.3700E-03	1.0000E+00	193	-1.0478E+03			
62	-5.7572E-02	2.5000E-02	194	-1.0777E+04			
65	7.6312E-05	1.2400E+01	195	-6.8161E+02			
66	-2.6043E-03	1.2400E+01	196	2.5401E+03			
69	-8.5017E-03		197	-1.6682E+00			
71	-4.0524E-02		198	1.0478E+03			
72	4.9108E-02		200	-8.4412E+01			
75	1.7631E-02		201	1.6834E+00			
81	2.3803E-01		202	3.8060E-06			
82	.0000E+00	4.5000E-01	203	-6.2570E-02			
83	3.0000E+03	4.6000E+00	204	3.0202E+06			
84	5.3873E+01		205	9.0456E+04			
85	1.5603E-01		208	-6.7297E+00			
91	1.0000E+00		209	-1.5709E+00			
99	1.0000E+00		210	6.0828E-05			
101	2.3262E-02		211	7.4571E-02			
102	1.2754E-02		212	8.9864E+01			
104	5.8917E-03		213	-1.5625E+03			
105	8.5206E-03		214	6.2310E+03			
106	9.7203E-03		215	-4.6751E+03			
107	8.5206E-03		216	1.8840E-06			
109	-1.0208E-02		218	1.1234E-01			
110	-2.4596E-05		219	-1.0805E-02			
111	-1.7436E-01		220	4.7101E-03			
112	2.9972E-01		221	1.0033E+00			
114	8.3481E-01		222	1.0000E+00			
115	5.8337E-01		223	2.7222E-01			
116	3.1050E-01		224	5.7773E+00			
117	1.2754E-02		225	1.8300E+02			
119	1.0000E+00		226	-4.7880E+04			
121	1.0000E+00		227	-2.7449E+01			
122	1.0000E+00		229	-6.3312E-01			
123	1.0000E+00		231	1.7117E+01			
131	7.5957E-02		232	-1.7472E+00			
132	-5.7573E-02		235	4.2206E+01	3.0000E-01		
133	-9.8341E-08		236	5.8922E-03	9.0000E-02		
134	-7.3700E-03		237	-1.0209E-02	9.0000E-02		
135	-5.7707E-07		240	1.0000E+00	2.0000E-01	1.0000E+00	
140	-5.7478E-05		241	-1.0000E+00			
143	1.6078E-06		242	-1.0731E-02			
146	-2.1191E-03		244	-1.2397E-02			
148	-2.5143E-01		246	2.5782E-01			
149	-3.0000E+03		248	3.0243E-01			

252	-1.3000E-01
258	4.0000E+01
269	1.0000E-02
276	5.7296E+01
277	5.7296E+01
278	5.7296E+01
279	5.7296E+01
280	5.7296E+01
281	5.7296E+01
282	5.7296E+01
283	5.7296E+01
284	5.7296E+01
285	5.7296E+01
286	5.7296E+01
287	5.9249E-01
288	5.9249E-01
289	-1.0000E+00
290	4.7040E+00
291	-1.0000E+00
292	5.7296E+01
293	5.7296E+01
294	5.7296E+01
295	5.7296E+01
296	-6.0000E+00
298	1.0018E+02
299	5.0000E-01
300	1.0300E+02
302	2.5000E+02
303	4.8600E+01

304	3.0000E+02	
313	1.1629E+03	4.5000E-01
314	5.6518E+04	1.5068E-01
315	7.3745E-01	2.6255E-01
317	9.2600E-05	
321	-1.0000E+00	
322	3.0000E-01	

FUNCTIONS

24

.0000E+00	.0000E+00
5.0000E+02	.0000E+00

51

.0000E+00	.0000E+00
5.0000E+02	.0000E+00

80

.0000E+00	3.0000E+03
5.0000E+02	3.0000E+03

158

.0000E+00	.0000E+00
5.0000E+02	.0000E+00

159

.0000E+00	.0000E+00
5.0000E+02	.0000E+00

APPENDIX D
Using Program ATMOS

A description is given below on how to use the program ATMOS, which provides density and speed of sound for given atmospheric conditions. ATMOS, together with its Fortran source file (atmos.f) and object file (atmos.o), are available on ARL magnetic tape M228.

The following types of atmosphere may be considered by setting the KEYAIR flag appropriately:

KEYAIR = 1	-	ICAO standard atmosphere
KEYAIR = 2	-	ICAO Sea-level conditions at all times
KEYAIR = 3	-	Off-Standard ICAO atmosphere
KEYAIR = 4	-	ARDU Tropical atmosphere
KEYAIR = 5	-	ARDU Sea-level conditions at all times
KEYAIR = 6	-	Off-Standard ARDU atmosphere

The example below shows how ATMOS can be used to find the air density and speed of sound for conditions typically found during the Sea King flight trials (Ref. 12):

```
:ATMOS
SET ATMOSPHERIC FLAG, KEYAIR (1,2,3,4,5 OR 6): 3
SINGLE CALCULATION, OR TABLE (1 OR 2): 1
STATE ALTITUDE (IN FEET): 3000
TEMPERATURE OF THE DAY, TDAY (IN DEG. C): 15
QNH OF THE DAY (IN MILLIBARS): 1025
HEIGHT OF THE AIRFIELD REFERENCE POINT, HAFR: 100
:
```

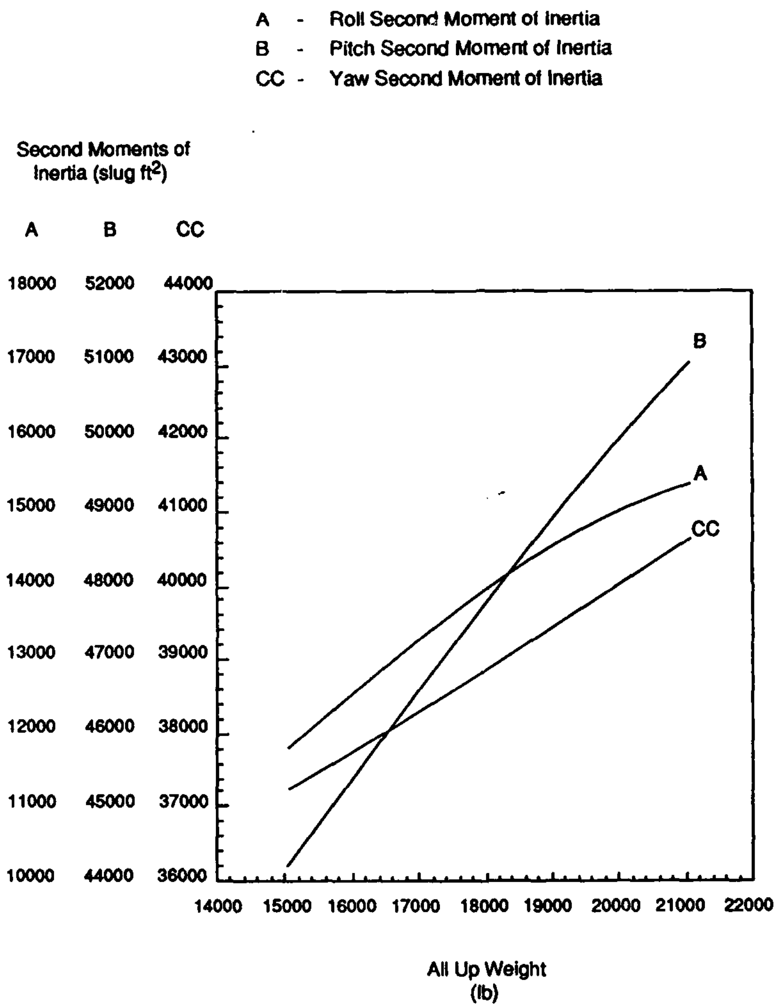
The results are stored in file ATMOS.OUT with each column representing the following quantities:

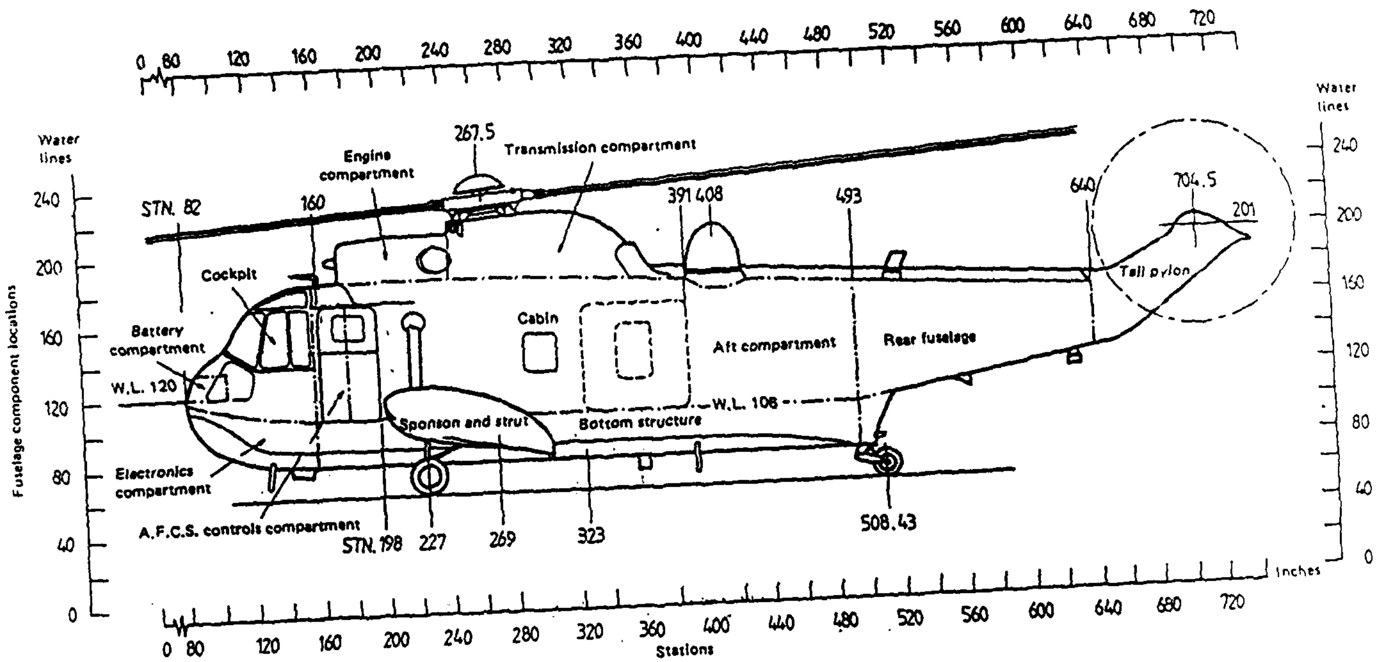
Column 1	-	Altitude (ft)
Column 2	-	Temperature (Kelvin)
Column 3	-	Pressure (lb/ft^2)
Column 4	-	Density (slug/ft^3)
Column 5	-	Speed of Sound (ft/s)

```
:LIST ATMOS.OUT
3000.0      282.40      1918.64      .0021988      1105.26
```

If the option of a table was chosen in the above example, ATMOS would calculate the atmospheric conditions from sea-level up to the stated altitude (3000 ft) in steps of 1000 ft.

APPENDIX E
Second Moments of Inertia vs. AUW



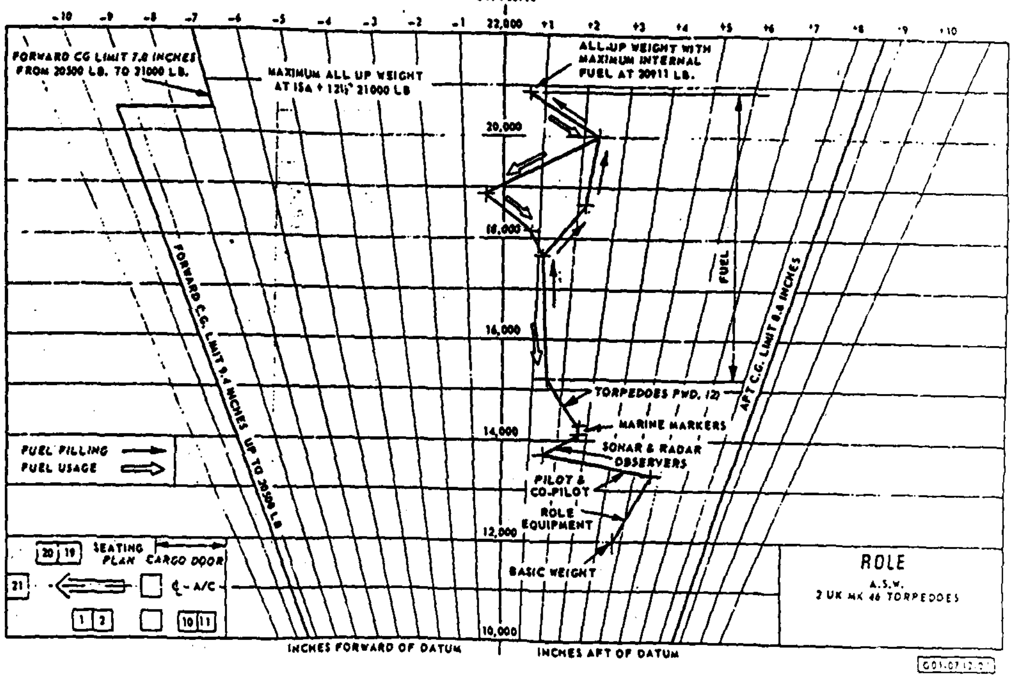


APPENDIX F - Fuselage Stations and Water Lines for Sea King Mk 50

LOADING TABLE

Primary role – Two UK Mk.46 torpedoes

Item		Weight (lb)	Moment (lb.in.)
Basic weight ...		12000	+ 57317
Role Equipment ...		1335	+ 18176
		13335	+ 75523
Pilot and Co-pilot ...		410	– 52808
		13745	+ 22715
Sonar Operator ...		205	+ 11603
Radar Operator ...		205	+ 10168
		14155	+ 44454
Marine Markers ...		48	– 769
		14203	+ 43687
UK Mk.46 Torpedoes 2 off ...		1068	– 18263
		15271	+ 25424
Signal Cartridges ...		8	– 805
		15279	+ 24619
AUW Less fuel ...		15279	+ 24619
Fuel filling to max. internal fuel	Fwd. ...	1208	– 63937
	Aft ...	1208	+ 60279
		17695	+ 21961
	Centre ...	456	– 1687
	Aft ...	456	+ 22754
		18607	+ 43028
	Aft ...	696	+ 34730
	Centre ...	221	– 818
	Fwd. ...	475	– 24748
		19999	+ 52192
	Fwd. ...	621	– 32354
	Centre ...	291	– 1077
		20911	+ 18761
Fuel Usage	Fwd. ...	– 604	+ 31468
	Centre ...	– 281	+ 1040
		20026	+ 51269
	Aft ...	– 1152	– 57485
		18874	– 6216
	Centre ...	– 231	+ 856
	Fwd. ...	– 492	+ 25634
		18151	+ 20274
	Centre ...	– 456	+ 1687
		17695	+ 21961
	Fwd. ...	– 1208	+ 62937
	Aft ...	– 1208	– 60279
		15279	+ 24619
C.G. at Takeoff weight ...			+ 0.897



APPENDIX G - Loading Table in Primary Role for Sea King Mk 50

APPENDIX H
Check Data File DATA.CHD

```
 $aer
,g =32.2000007 ,rhoa =2.37699993E-03 ,rhow =1.98399996 ,spsnd =1116.44995
,hmass =575.0 ,a =14275.0 ,b =48375.0 ,cc =39150.0 ,eit =10800.0
,onemze = .823000013 ,thetal =-.138999998 ,gamma =10.7600002 ,delta =1.20000001E-02
,r2 = 31.0 ,zeta0 =3.39000001E-02 ,sigma =7.80000016E-02 ,thsh =-6.97999969E-02
,blmn =5.0 ,ekappa =.305000007 ,ek3 =7.99999982E-02 ,ek4 =1.90300005E-03
,ek5 = .159999996 ,onemzt =.76999998 ,gammat =5.0999999 ,sigmat =.224000006
,rt = 5.21000003 ,bltl =6.0 ,fgloss =1.03999996 ,rpmset =209.0 ,shpmax = 2778.0
,grrat =6.12699985 ,eki =2.0 ,ei =.0 ,sth =19.3999996 ,stv = 21.5
,strf =.0 ,sx =102.0 ,sy =415.0 ,sz =318.0 ,smalla =7.1999998 ,ekth = 1.0
,alths =.192000001 ,altvs =.192000001 ,ath =3.5 ,atv =4.3499999
,cdxf = .342999994 ,cdyf =.76999998 ,cdzf =.699999988 ,cdth =1.17999994
,cdtv = 1.86000001 ,alphal =-8.73000025E-02 ,alphad =-.104699999 ,eff4 =.5
,sclal = 225.0 ,scdal =230.0 ,scmbod =5000.0 ,scduc =.0 ,scdwep =.0
,scmuc = .0 ,scmwep =.0 ,hr =7.1999998 ,hrot0 =15.5 ,ht =4.75 ,elt =36.5
,elth = 36.2999992 ,eltv =34.4000015 ,htv =2.5 ,dth =3.0 ,hf =1.5 ,kih =1.10000002
, kihtr =1.39999997 ,kal =1.0 ,ntbl1 =12 ,ntbl2 =12 ,ntbl3 =10 ,ntbl4 = 6 $

   .0000E+00  3.2900E+00  3.5000E-01  3.2900E+00  7.9000E-01  2.1600E+00
  1.0500E+00  1.9500E+00  1.2200E+00  1.6500E+00  1.5700E+00  1.2700E+00

 -1.0000E-01   .0000E+00   .0000E+00  8.0000E-02  8.5000E-02  2.3500E+00
  1.5000E-01  2.3500E+00  3.0000E-01   .0000E+00  5.0000E-01   .0000E+00

   .0000E+00 -4.0000E+00  2.6000E-01 -4.0000E+00  4.4000E-01   .0000E+00
  1.0000E+00  5.5000E+00  1.5700E+00  5.5000E+00

 -2.0000E+02 -6.2112E+04   .0000E+00 -1.5528E+04  2.0000E+02 -6.2112E+04

 $sys
,cp1 =.746900022 ,cp2 =.370000004 ,cp3 =.5 ,cp4 =.680000007
,cp5 =3.51299997E-03 ,cp6 =2.16999993E-04 ,cp9 =5.40999993E-02 ,cp10 =15.3100004
,cp11 =1.49999996E-02 ,cp12 =1.30000002E-02 ,cp13 =9.99999974E-06
,cp14 =8.79999995E-03 ,cp15 =1.80000002E-04 ,cp16 =.153999999 ,tp1 =7.00000002E-02
,elap =.269149988 ,elbp =1.99999995E-02 ,elcp =.305400013 ,cp17 =15.3985004
,cp18 =1.0 ,cp19 =.159999996 ,cr1 =.462599992 ,cr2 =1.39999997
,cr3 =.200000002 ,cr4 =.129999995 ,cr5 =7.23299989E-03 ,cr6 =2.26999996E-04
,cr9 =8.37699994E-02 ,cr10 =15.3100004 ,cr11 =1.85000002E-02 ,cr12 =1.79999992E-02
,cr13 =1.40000001E-05 ,cr14 =4.69999993E-03 ,cr15 =4.79999987E-04
,cr16 =.165999993 ,cr17 =11.5860004 ,cr18 =1.0 ,cr19 =6.93999975E-02
,tr1 =2.50000003E-02 ,tr2 =.100000001 ,tr3 =1.0 ,elar =.269149988
,elbr =1.32600003E-02 ,elcr =.290899991 ,cy1 =3.91599988 ,cy2 =6.97999969E-02
,cy3 =89.0 ,cy4 =23.3500003 ,cy5 =4.37799978 ,cy6 =2.01999998 ,cy7 =.365200012
,cy8 =1.0 ,cy9 =.211999997 ,cy10 =3.71000001E-04 ,cy11 =2.2019999
,cy12 =1.03110003 ,cy13 =165.899993 ,elay =4.0 ,elcy =.303499996
,eloy =1.75000005E-03 ,cc1 =1.29729998 ,cc2 =.108199998 ,cc3 =.148399993
,cc4 =1.96099996 ,cc5 =2.43799996 ,cc6 =1.06399999E-02 ,cc7 =30.8799991
,cc8 =1.0 ,cc9 =.221 ,cc10 =5.61000022E-04 ,cc11 =100.0 ,cc12 =.646600008
,cc13 =273.299987 ,cc14 =165.899993 ,cc15 =.0 ,elac =4.0 ,eloc =5.07699977E-03
,elmax =.314099997 ,elmin =.0 ,cc16 =30.8799991 ,tmp =.25 ,tsmp =1.75
,tmr =.25 ,tsmr =4.0999999 $
```

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16. ABSTRACT A mathematical model of the Sea King Mk 50 helicopter, as used in the Anti-Submarine Warfare (ASW) role, has been developed at ARL. This document describes the basic use of the computer program representing this model on the ELXSI 6400. Details are given on setting up the model and running it, first in ASW mode as a means of trimming the aircraft, and then in either ASW, ASE (Auto Stabilizing Equipment), or pilot modes to simulate a desired manoeuvre.

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21. COMPUTER PROGRAMS USED

22. ESTABLISHMENT FILE REF.(S)

23. ADDITIONAL INFORMATION (AS REQUIRED)